RED BLOOD CELL COUNTS
PHOTOELECTRIC - HAEMACYTOMETER
WITH CORRECTION FACTORS FOR
ABNORMAL CELLS*

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The purpose of this paper is to demonstrate the usefulness of
the photoelectric colorimeter as an instrument for the accurate esti-
mation of the erythrocytes in both normal and abnormal blood. This
was determined by the application of correction factors for corpus-
cular hemoglobin concentration in per cent and for the mean cell
diameter.

In 1929 Exton (1, 2, 3) published a report of 42 cases of blood
counts showing a correlation between the haemacytometer method
and the measurement of the turbidity of the blood cells in suspension
as determined by the Photo Electric Scopometer. The Photo-
electric Colorimeter needs no lengthy introduction. The instrument
used in this study was the Evelyn (4) type which offers a means of
determining with speed, accuracy, ease of manipulation and economy

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of material the erythrocytes of the blood. Evelyn (5) states that the photoelectric colorimeter becomes a nephelometer when measuring the opacity of red blood cells in suspension by the use of the red filter which eliminates the absorption of hemoglobin.

Shohl (6) attributes the phenomenon of the obstruction of light to particles in suspension, varying according to size, shape and opacity. This may account for the difference between the nephelometer reading and the haemacytometer and hematocrit determinations of suspensions of the same specimen of blood, containing hypo or hyperchromic, macrocytic or microcytic cells.

It has been suggested that in abnormal blood it might be necessary to revert to determinations by haemacytometer and hematocrit. This would eliminate in part the usefulness of the photoelectric colorimeter. To do part of the erythrocyte determination by the colorimeter and if the result is doubtful to use the haemacytometer and hematocrit, is like hitching a horse to an automobile to get it out of the mud. The question would be, "When to be in doubt?"

The manometric method of determining the hemoglobin by oxygen capacity, described by Van Slyke and Neill (7) is the only absolutely accurate procedure. The manual manipulation of the manometer is very simple, the technique precise. Ordinarily a single reading of the volume of gas first extracted is all that is necessary. The result is calculated by a factor which includes all the corrections for temperature, mercury pressure, vapor tension, carbon dioxide and nitrogen.

For the purpose of making the photoelectric colorimeter applicable in abnormal blood determinations, I have devised the necessary correction factors.

Wintrobe's (8) formula for the mean corpuscular hemoglobin concentration in per cent is used to obtain one of these factors. This is not an arbitrary standard but depends on the volume of red blood cells and the hemoglobin content of the cells.

The second factor is the correction for the deviation of the cell diameter from the normal. This abnormality of cells has been the

stumbling block interfering with the determination of the red blood cell count by the opacity method.

Cell diameter determinations are not done routinely because the methods have been impractical, complicated, laborious and time consuming. Some writers state that too little thought is given to this important feature. Davidsohn (9) states that the study of the unstained smear is of greatest importance. Medical technologists should report the incidence of microcytes, macrocytes, anisocytosis and poikilocytosis from the unstained smear. After the examination of the stained slide they report, hyper or hypochromasia.

The Price Jones (10) method of cell diameter determination, employs the reflection of cells from the microscope on to a screen several feet away and their measurement. The final result takes the magnification into consideration. This procedure requires special technique and two technicians; one to measure the cell, the other to record. Using this system, one slide would be a day's work.

The halo method (11) employs a kodak. The light passes through the smear which is held tight to the lense by means of rubber bands, and the cell outlines are reflected on a sheet of transparent paper which is marked in centimeter divisions and pulled over the film portion of the box. This method is inaccurate and time consuming.

Spreading the ruled portion of the haemacytometer with blood and observing under the oil immersion objective allows one to estimate the diameter of the cells. Each one-sixteenth space of the center divisions measures 1/20 millimeter square or 50 microns and theoretically should contain 43.5 cells of normal diameter. The trouble is that the cells refuse to fall in their place and the imagination has to work overtime to fill in the missing space.

The Haden-Hausser (12) Erthrocytometer utilizes a principle similar to that of the halo method. Instead of accurately ruled paper, a disk, containing apertures of two sizes, is placed within a cylinder above the light and below the slide on which the blood has been smeared and stained. The light passing through the blood film forms a bright spectrum which is visible by looking into the top of

the instrument. The mean cell diameter, as determined by the distance of the cells from the light source, is read directly in microns from the scale engraved around the adjustment wheel. Optical defects in the technician could cause conflicting results. One person could become an expert, but this would not be practical since his results would not tally with those of another expert.

The Camera Lucida is not a stranger in the laboratory. You have employed it for years in the sketching of cells and bacteria. It can be used to determine the cell diameters. By using the moveable scale described later as the Hemo-Protractor (13) all the cells of an entire field may be measured in a very few minutes. This Hemo-Protractor is designed for a magnification of 1000 millimeters. If the magnification of the microscope is known, accurate readings may be obtained by adjusting the Hemo-Protractor above, on, or below the stage. The microscope used in this research is a Leitz Binocular which also has a monocular tube. This enabled me to observe the slide as for a routine differential, remove the binocular tube and replace it with the monocular tube to which the Camera Lucida was attached with the mirror at the proper angle. This manipulation is simple. The tabulation of the cell diameters of 500 or 1000 cells may be done in the length of time required to do a differential blood smear—at least after the first one hundred slides.

If a large percentage of the cells on a blood film are micro or macrocytic you realize why your nephelometric red cell count does not correspond to your haemacytometer count. After applying the correction factor for cell diameter the two figures will correspond within a close range of each other.

There has been some question as to the value of this computation, of what importance is it if four million cells are doing the work and carrying the hemoglobin that three million cells could carry, or the condition is reversed, and four million cells are doing the work of six million. Although the data is not available at this time to show that therapy definitely normalizes cells as regards hemoglobin and cell diameter, this has been observed by some hematologists.*

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* Personal communication from Katsuji Kato, Ph.D., M.D. of the University of Chicago.

Blood specimens used in this study are both venous and capillary. However, I am not sure that capillary blood actually is obtained by deep heel or plantar surface toe punctures resulting in free flowing blood .

Comparison studies were done, using dilutions made at the bed-side and from blood specimens to which an anticoagulant (14) had been added, and dilutions completed in the laboratory. The longest interval between ward and laboratory procedure was one hour, the average being thirty minutes. However, it was found that after two hours no change was observed in the readings of the original samples that were double oxalated.

Technique of Obtaining Blood Samples: Using an all glass syringe and a 1¼ inch 22 gauge Luer needle, blood is drawn from the external jugular vein. Removing the needle from the syringe, one drop of blood is placed on a slide and a thin film spread over the slide by means of another slide held at a forty-five degree angle. One c.c. of the blood is placed in a vial containing the dry crystals of 50 cubic millimeters of a two per cent double oxalate and mixed thoroughly. This vial of oxalated blood is used in the laboratory for dilutions for counts, etc. The remaining blood is placed in a test tube and is used for chemistry and serology. With an experienced operator, the whole procedure from the time the needle is inserted in the vein requires one minute. A tourniquet is placed above the knee in doing heel punctures. After cleansing with alcohol and drying the skin, the area of the heel to be used for the puncture is covered with sterile vaseline. The puncture is made with a sharp narrow scalpel, and the incision is parallel with the longitudinal tendons about where the capillary plexus of the saphenous and the posterior tibial vein passes over the medial side of the foot. The blood flows freely without pressure, is collected in the vial, and mixed as it drops into the dried oxalate (these vials are file-marked at one cubic centimeter). A drop of free blood is caught and a slide smeared. This facilitates collecting samples in large numbers and returning to the laboratory where dilutions are carried out with accuracy. I have collected twelve specimens of blood in a half hour.

Calibrating the Photoelectric Colorimeter

Red Cell Count is million per cubic millimeter of blood, requires five colorimeter tubes each containing ten cubic centimeters of three per cent sodium citrate and 5, 10, 15, 20 and 25 cubic millimeters of blood respectively. Galvanometer readings are recorded and plotted on semi-logarithmic paper. In this research the constant was found to be 0.045 ± 0.0003 using filter number six-sixty (#660). The haemacytometer count was used as a guide in calculating the number of cells in the various dilutions.

Volume Per Cent (15) as determined from the cell opacity was compared to that determined by the centrifugal method using the Van Allen Hematocrit (16) tube without adding the diluting fluid. This diluting fluid causes shrinkage of the cells and greatly reduces the volume per cent. The method used in this study checked exactly with results obtained by the Kato combination micropipet (14) with the double oxalate in proportion one to five hundred (1:500). This does not shrink cells and gives results comparable to those obtained when heparin is used as the anticoagulant. The constant value of K_2 for the volume per cent was found to be 0.0048 ± 0.0002 using filter number six-sixty (#660).

The calibration for Oxyhemoglobin (17) was carried out following the instruction supplied with the instrument, except that a three per cent sodium citrate solution as suggested by Diamond (18) was substituted for the weak ammonia water. The sample of blood chosen for the plotting of the curve gave a combined oxygen capacity of 20.9 cc. per 100 cc. of blood and 15.6 grams of hemoglobin per 100 cc. of blood, according to Peters & Van Slyke (19). The constant value of K_2 for grams of hemoglobin was found to be 2.60 ± 0.01 using filter number five-forty (#540).

Table one (I) represents a sample of the work chart used to read the results direct according to the deflection of the galvanometer. In doing routine determinations twenty cubic millimeters (20.cu.mm) of blood is diluted with ten cubic centimeters (10 cc.) of three per cent sodium citrate, mixed thoroughly, using filter number six-sixty (#660), the galvanometer readings are taken from the

three-way chart (Table I) and recorded as erythrocyte count or volume per cent or both. The filter is changed to number five-forty (#540); one drop or fifty cubic millimeters (50 cu. mm) of twenty per cent (20%) white saponin is added to the suspension in the tube to lake the blood and two drops of ammonium hydroxide are added to clear it. The galvanometer reading is taken from the three-way chart for the hemoglobin content. This whole procedure requires approximately three minutes.

Since making this three-way table, I find that taking the volume per cent and the hemoglobin is sufficient to determine the red blood cell count by employing the Wintrobe formula to obtain the corpuscular hemoglobin concentration per cent. When the corpuscular hemoglobin concentration per cent (C.C.%) is other than thirty-three and three tenths (33.3%) per cent reference is made to the correction factor table. If the cells are of normal diameter the correction factor corresponding to the corpuscular hemoglobin concentration per cent multiplied by five times the percentage of hemoglobin, gives the figure that should have been obtained by the haemacytometer count. Table two (II) Correction Factors for the Corpuscular Hemoglobin Concentration Per cent. (Remember the C.C. per cent is entirely dependent upon the absolute figures obtained from dividing the hemoglobin grams by the volume per cent of blood.)

Table three (III) shows determinations made from the hemoglobin grams and the volume per cent. The red blood cell count as determined by this method and by the haemacytometer are within range of error.

Cell Diameter

When observation of blood smears revealed abnormality in the size of the cells, the Camera Lucida was attached and the cell diameters were tabulated similar to the method employed in counting a differential white count. We considered the normal diameter to be seven and one half microns (7.5). Plate one (I) shows the Camera Lucida in place with the scale for measuring the cell diameter. Illumination is from a microscopic lamp.

Plate two (II) shows an enlargement of the Hemo-Protractor. The square of the Hemo-Protractor measures five by five centi-
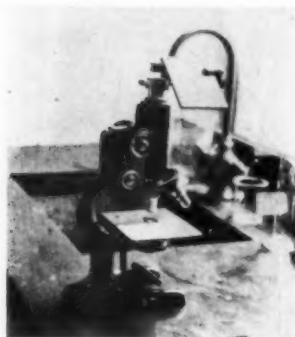
PLATE I

Kato and Kortuem—Camera Lucida Method of Direct Hemocytometry with
new Hemo-Protractor

meters. This enables the operator to adjust the distance that the
Hemo-Protractor should be from the stage to give the one thousand
magnification, by fitting this square into one of the center squares of
the haemacytometer. To do this view the center portion of the
haemacytometer with the oil immersion objective through the ocular
of the Camera Lucida and adjust the mirror so as to p'ace the reflec-
tion of the ruled portion of the haemacytometer convenient for
handling the Hemo-Protractor, preferably two inches from the ob-
jective. The magnification of the microscope used in this study is
1085 which necessitated keeping the Hemo-Protractor one inch above
the stage. The ruling of the Hemo-Protractor makes it convenient
not only for the erythrocytes but also for the leucocytes of the Blood.
Millimeter—1 micron.

The table of correction factors for the mean cell diameter was
made by multiplying the blood count (determined by the opacity
method) by the difference in per cent of the cell diameter from the
normal. Example: The mean cell diameter which corresponds to
the mode of distribution is six (6.0) microns and the galvanometer
deflection would denote three million cells per cubic millimeter of
blood: It will be noted from the correction table that three million
crosses with the correction factor for six (6.0) microns or 1.25 from
normal (7.5 microns). Reading direct from the table, the corrected
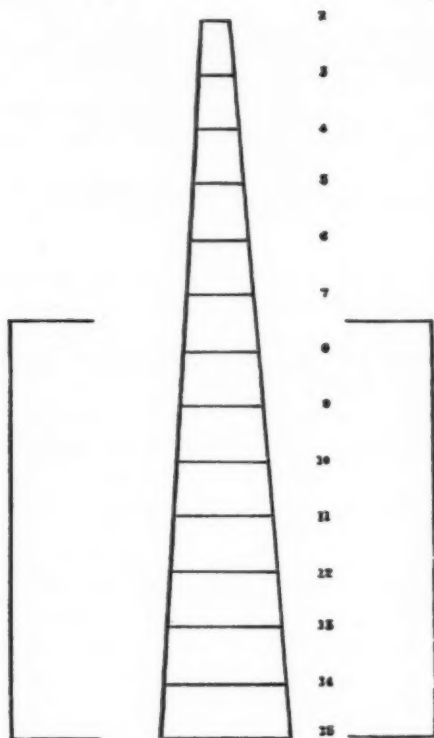
MAGNIFICATION
500
M.M. = 1 Micron

PLATE II

H E M O - P R O T R A C T O R

(Enlarged 1¼ times)

Editor's Note: Original plate (enlarged 2½ times) 1,000 M.M. = 1 micron has been reduced for illustrative purposes one-half size.

red blood count would be three million and seven hundred and fifty thousand per cubic millimeter of blood. The haemacytometer count three million eight hundred thousand.

Both Correction Factors: In extremely abnormal bloods it may be necessary to apply both correction factors; one for the corpuscular hemoglobin concentration per cent and one for the cell diameter. Tables five (V) and six (VI) are illustrating the blood pictures in Cooley's Anemia and in Goat Blood. The cells of goat blood differ greatly from those of human blood. Since the photoelectric colorimeter is calibrated for normal blood and it takes two and fifteen hundreds goat cells to make one normal human cell, this factor is applied giving a comparable count to the haemacytometer count. A human may have some cells measuring three and one half (3.5) microns (which is the average cell size of goat blood) but there are sufficient larger cells to raise the mean value.

Chart I—This chart offers an actual comparison study of venous and capillary blood from the same infants. The blood specimens were taken at the same time. The venous blood determinations were made from blood that had been oxalated with double oxalate in proportions of one to five hundred (1:500). The capillary blood direct from the puncture was diluted with ten cubic centimeters (10 cc.) of three per cent sodium citrate. The total leucocytes are reported to prove that their volume did not influence the reading of the hematocrit or colorimeter. Application of the corpuscular hemoglobin concentration per cent correction factor was used in all cases. The calculated erythrocyte count is within range of error of the haemacytometer count. Occasional application of the correction factor for cell diameter was employed.

Charts II & III. These charts give readings to which no correction factor was applied. The standard deviation, the coefficient of variation, the difference between the two means and the significance of the difference between the two means, prove that there is no significant difference between the photolometer and the haemacytometer counts. The statistical data in this study was collected on 1061 counts of males and 530 counts of females. The children ranged in age from birth to 54 months and were grouped in two week periods up to one

month of age, and thereafter in one month periods until the twelfth month. The variation after the twelfth month (20) was not appreciable and the size of the samples did not warrant further breaking down into monthly groups.

Advantages: Possibilities of mechanical error are diminished to a minimum in red blood count and hemoglobin determinations by use of the photoelectric colorimeter.   More attention is directed to a neglected laboratory procedure; namely, the measurement of the diameter of the blood cells.   The application of arithmetic figures saves time and eyesight for the technologist and gives the hematologist complete accurate data for the institution of proper therapy.

Conclusion: The photoelectric colorimeter, which has been accepted and approved for normal hematologic determinations, has been used with satisfactory results in our laboratory by applying the correction factors I devised to abnormal or pathological specimens of blood.

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TABLE I

| Filter #540 K_2 2.60 | | | | Filter #660 K_2 0.045 & 0.0048 | | Filter #540 K_2 2.60 | | | | Filter #660 K_2 0.045 & 0.0048 | |
| | | Hemoglobin | | Rbc/cmm & Volume | | | | Hemoglobin | | Rbc/cmm & Volume | |
G'	G	gms	%	(X 10^6)	%	G'	G	gms	%	(X 10^6)	%
$75'$	74	5.05	32	2.90	27.2	$61'$	59^3	8.60	55	4.96	46.5
75	73^3	5.08	33	2.93	27.5	61	59^2	8.67	55	5.01	46.8
74^3	73^2	5.14	33	2.97	27.8	60^3	59^1	8.74	56	5.05	47.3
74^2	73^1	5.20	33	3.00	28.1	60^2	59	8.81	56	5.09	47.7
74^1	73	5.25	34	3.03	28.4	60^1	58^3	8.88	57	5.13	48.0
74	72^3	5.31	34	3.07	28.7	60	58^2	8.95	57	5.17	48.4
73^3	72^2	5.37	34	3.10	29.0	59^3	58^1	9.03	58	5.21	48.8
73^2	72^1	5.43	35	3.13	29.3	59^2	58	9.10	58	5.25	49.2
73^1	72	5.48	35	3.17	29.6	59^1	57^3	9.17	59	5.29	49.5
73	71^3	5.54	35	3.20	29.9	59	57^2	9.24	59	5.34	49.8
72^3	71^2	5.66	36	3.23	30.2	58^3	57^1	9.32	60	5.38	50.2
72^2	71^1	5.71	36	3.27	30.5	58^2	57	9.39	60	5.42	50.5
72^1	70	5.78	37	3.30	30.9	58^1	56^3	9.46	60	5.46	51.2
72	70^3	5.83	37	3.34	31.3	58	56^2	9.54	61	5.51	51.6
71^3	70^2	5.90	38	3.37	31.6	57^3	56^1	9.61	61	5.54	52.0
71^2	70^1	5.93	38	3.40	31.9	57^2	56	9.69	62	5.59	52.4
71^1	69^3	6.01	39	3.44	32.2	57^1	55^3	9.76	62	5.64	52.7
71	69^2	6.07	39	3.47	32.5	57	55^2	9.83	63	5.68	53.2
70^3	69^1	6.13	39	3.51	32.8	56^3	55^1	9.91	63	5.72	53.6
70^2	69	6.20	40	3.54	33.2	56^2	55	9.99	64	5.76	54.0
70^1	68^3	6.25	40	3.58	33.5	56^1	54^3	10.06	64	5.81	54.5
70	68^2	6.31	40	3.61	33.8	56	54^2	10.14	65	5.85	54.9
69^3	68^1	6.38	41	3.65	34.2	55^3	54^1	10.22	65	5.90	55.3
69^2	68	6.44	41	3.68	34.5	55^2	54	10.29	66	5.94	55.7
69^1	67^3	6.50	42	3.72	34.8	55^1	53^3	10.37	66	5.99	56.1
69	67^2	6.56	42	3.75	35.2	55	53^2	10.45	67	6.03	56.5
68^3	67^1	6.61	42	3.79	35.5	54^3	53^1	10.52	67	6.08	57.0
68^2	67	6.68	43	3.82	35.8	54^2	53	10.60	68	6.12	57.4
68^1	66^3	6.75	43	3.86	36.2	54^1	52^3	10.68	68	6.17	57.7
68	66^2	6.82	43	3.90	36.5	54	52^2	10.76	69	6.21	58.2
67^3	66^1	6.87	44	3.93	36.8	53^3	52^1	10.84	69	6.28	58.6
67^2	66	6.94	44	3.97	37.2	53^2	52	10.92	70	6.31	59.1
67^1	65^3	7.00	45	4.01	37.5	53^1	51^3	11.00	70	6.35	59.5
67	65^2	7.07	45	4.04	37.8	52	51^2	11.08	71	6.39	60.0
66^3	65^1	7.13	46	4.08	38.2	52^3	51^1	11.17	72	6.45	60.4
66^2	65	7.20	46	4.12	38.5	52^2	51	11.25	72	6.49	60.7
66^1	64^3	7.26	46	4.15	38.8	52^1	50^3	11.35	73	6.55	
66	64^2	7.33	47	4.19	39.3	51	50^2	11.41	73	6.60	
65^3	64^1	7.39	47	4.23	39.6	51^3	50^1	11.50	74	6.64	
65^2	64	7.46	48	4.27	40.0	51^2	50	11.58	74	6.68	
65^1	63^3	7.52	48	4.30	40.3	51^1	49^3	11.66	75		
65	63^2	7.59	49	4.34	40.7	50	49^2	11.75	75		
64^3	63^1	7.65	49	4.38	41.2	50^3	49^1	11.84	76		
64^2	63	7.72	49	4.42	41.5	50^2	49	11.92	76		

TABLE II

FACTORS FOR CORPUSCULAR HEMOGLOBIN CONCENTRATION (C.C.) PER CENT

C.C.%	C.F.	C.C.%	C.F.	C.C.%	C.F.	C.C.%	C.F.
20.0 -	1.665	30.0 -	1.110	40.0 -	0.832	50.0 -	0.666
20.5 -	1.624	30.5 -	1.091	40.5 -	0.822	50.5 -	0.659
21.0 -	1.585	31.0 -	1.074	41.0 -	0.812	51.0 -	0.653
21.5 -	1.548	31.5 -	1.057	41.5 -	0.802	51.5 -	0.646
22.0 -	1.513	32.0 -	1.040	42.0 -	0.792	52.0 -	0.640
22.5 -	1.480	32.5 -	1.024	42.5 -	0.783	52.5 -	0.634
23.0 -	1.447	33.0 -	1.008	43.0 -	0.774	53.0 -	0.628
23.5 -	1.417	33.5 -	0.994	43.5 -	0.765	53.5 -	0.622
24.0 -	1.387	34.0 -	0.979	44.0 -	0.756	54.0 -	0.616
24.5 -	1.359	34.5 -	0.965	44.5 -	0.748	54.5 -	0.611
25.0 -	1.332	35.0 -	0.951	45.0 -	0.740	55.0 -	0.605
25.5 -	1.305	35.5 -	0.938	45.5 -	0.731	55.5 -	0.600
26.0 -	1.280	36.0 -	0.925	46.0 -	0.720	56.0 -	0.594
26.5 -	1.256	36.5 -	0.912	46.5 -	0.716	56.5 -	0.589
27.0 -	1.233	37.0 -	0.900	47.0 -	0.707	57.0 -	0.584
27.5 -	1.210	37.5 -	0.888	47.5 -	0.701	57.5 -	0.579
28.0 -	1.189	38.0 -	0.876	48.0 -	0.693	58.0 -	0.574
28.5 -	1.168	38.5 -	0.864	48.5 -	0.686	58.5 -	0.570
29.0 -	1.148	39.0 -	0.853	49.0 -	0.679	59.0 -	0.564
29.5 -	1.128	39.5 -	0.843	49.5 -	0.672	59.5 -	0.559

Correction Factor Formula: From Wintrobe, Ref. J. Lab. & Clin. Med., 17, 899, 1932.

$$\frac{\text{Hemoglobin (grams per 100 cc blood)}}{\text{Volume of packed red blood cells (in cc. per 100 cc. of blood)}} = \text{Mean Corpuscular Hgb. Concentration (C.C. \%).}$$

Multiply the Red Blood count in millions (as read from the colorimeter table) by the correction factor listed in table above corresponding to C.C. % as determined from Wintrobe formula. This will give the corrected Red Blood count in millions per cu. mm.

TABLE III

Hemoglobin Gms. % Per 100 cc.		Volume %	C. C. %	C. F. for C. C. %			Corrected R. B. C. X 10⁶	Haemacytometer R. B. C. X 10⁶
10.60	68	31.5	33.6	0.992	x	3.40	3.37	3.40
10.60	68	31.0	34.2	0.976	x	3.40	3.32	3.50
11.84	76	35.0	33.8	0.984	x	3.80	3.74	3.60
11.75	75	32.0	36.7	0.909	x	3.75	3.41	3.25
11.00	70	34.0	32.3	1.030	x	3.50	3.60	3.40
12.18	78	36.0	33.8	0.984	x	3.90	3.84	3.89
12.78	82	37.0	34.5	0.965	x	4.10	3.97	4.04
11.66	75	35.5	32.7	1.020	x	3.75	4.50	4.30
13.63	88	39.0	34.9	0.949	x	4.40	4.18	4.28
13.63	88	38.5	35.4	0.940	x	4.40	3.79	3.80
12.00	77	35.5	33.8	0.982	x	3.85	3.46	3.55
13.63	88	39.0	35.0	0.951	x	4.40	4.18	4.10
12.18	78	34.0	34.0	0.979	x	3.90	3.83	3.85
13.63	88	38.5	35.4	0.940	x	4.40	4.14	4.10
14.12	90	36.5	38.6	0.860	x	4.50	3.87	4.05
11.08	71	31.5	35.1	0.950	x	3.55	3.37	3.35
12.27	79	35.0	35.0	0.951	x	3.85	3.66	3.71
11.50	74	33.0	34.8	0.948	x	3.70	3.50	3.60
12.78	82	39.0	32.6	1.020	x	4.10	4.18	4.12

The above chart shows the Erythrocyte count after applying the correction factor (C.F.) for corpuscular hemoglobin concentration per cent (C. C. %) to 5 times the % of Hemoglobin as compared to the Haemacytometer count.

TABLE IV

CORRECTION TABLE FOR CELL DIAMETER

C.F.	1.87	1.66	1.50	1.36	1.25	1.15	1.07	1.00	0.93	0.88	0.83	0.78	0.75	0.71	0.68
%	+85	+65	+50	+35	+25	+15	+07	±00	-07	-12	-18	-20	-25	-30	-35
μ	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
	0.94	0.83	0.75	0.68	0.63	0.58	0.54	0.50	0.93	0.88	0.83	0.78	0.75	0.71	0.68
	1.87	1.66	1.50	1.36	1.25	1.15	1.07	1.00	1.40	1.32	1.25	1.17	1.13	1.07	1.02
	2.81	2.49	2.25	2.04	1.88	1.73	1.61	1.50	1.86	1.76	1.66	1.56	1.50	1.42	1.36
	3.74	3.32	3.00	2.72	2.50	2.30	2.14	2.00	2.33	2.20	2.08	1.95	1.88	1.78	1.70
	4.68	4.15	3.75	3.40	3.13	2.88	2.68	2.50	2.79	2.64	2.49	2.34	2.25	2.13	2.04
	5.61	4.98	4.50	4.08	3.75	3.45	3.21	3.00	3.26	3.08	2.91	2.73	2.63	2.49	2.38
	6.54	5.81	5.25	4.76	4.38	4.03	3.75	3.50	3.72	3.52	3.32	3.12	3.00	2.84	2.72
	7.48	6.64	6.00	5.44	5.00	4.60	4.28	4.00	4.19	3.96	3.74	3.51	3.38	3.20	3.06
	8.42	7.47	6.75	6.12	5.63	5.18	4.82	4.50	4.64	4.40	4.15	3.90	3.75	3.55	3.40
	9.35	8.30	7.50	6.86	6.25	5.75	5.35	5.00	5.11	4.84	4.57	4.29	4.13	3.91	3.74
		9.13	8.25	7.48	6.88	6.22	5.89	5.50	5.58	5.28	5.98	4.68	4.50	4.26	4.08
			9.00	8.16	7.50	6.90	6.42	6.00	6.05	5.72	5.39	5.07	4.88	4.61	4.42
				8.84	8.13	7.48	6.96	6.50	6.51	5.16	5.81	5.46	5.25	4.97	4.76
					8.75	8.05	7.49	7.00	6.98	6.60	6.23	5.85	5.63	5.32	5.10
						8.62	8.03	7.50							

(Left-column label: Erythrocytes X10⁶ per cubic millimeter of blood)

The center column of figures represents the Red Blood cell count as determined by the photoelectric colorimeter. The figures to the left and right of this column of figures represent what the erythrocyte count should be after applying correction factor according to the Mean Cell Diameter in Microns.

Example: Galvanometer gives a reading for 4.89×10^6 / cu. mm. The cell diameter is 6.5 μ, the C. F. of 1.15×4.89 or 5.62×10^6 / cu.mm. of blood. If you wish to record, 15% of the cells are 6.5 μ or 0.15×4.89 or 5.62×10^6 / cu.mm. of blood.

TABLES V & VI

COOLEY'S ANEMIA

Photoelectric Colorimeter & Haemacytometer & Hematocrit

Gms.	7.920	Hemoglobin		
%	29.400	Volume	31.0	%
%	26.900	Cell Conc.	25.0	%
%	1.238	C. F. for C. C.	1.305	%
$x10^6$	3.160	Corrected RBC	3.380	$x10^6$
μ	9.000	Mean Cell Diam.	9.000	μ
%	0.830	C. F. for M. C. D.	0.830	%
$x10^6$	2.620	Corrected RBC.	2.810	$x10^6$
$x10^5$	3.130	RBC. count	2.72	$x10^5$

GOAT'S BLOOD

Photoelectric Colorimeter & Haemacytometer & Hematocrit

Gms.	12.780	Hemoglobin		
%	29.500	Volume	28.500	%
%	43.300	Cell Conc.	44.000	%
%	0.769	C. F. for C. C. %	0.756	%
$x10^6$	3.150	Corrected RBC.	3.100	$x10^6$
μ	3.500	Mean Cell Diam.	3.500	μ
%	2.140	C. F. for M. C. D.	2.140	%
$x10^6$	6.741	Corrected RBC.	6.634	$x10^6$
%	2.150	Correction for Standard	2.150	%
$x10^6$	14.583	Final Corrected RBC.	14.263	$x10^6$
$x10^5$	3.190	RBC. count	14.539	$x10^5$

CHART I

Age in Mos.	Sex	Blood Capillary or Venous	Hemoglobin (15.6-100%) Gms.—%	Red Blood Counts X10⁶ Photoelectric	Corrected Haemocytometer	Corrected RBC	Mean Cell Vol. %	Mean Cell Cont. Hgb. %	Correction Factor (C. C. %)	Mean Cell Diameter in Microns	Correction Factor (Mean cell diameter)	Corrected Red Blood Count x10⁶	Calcium Mgm per 100 cc.	Phosphorus Mgm per 100 cc.	Total Leucocyte Count	Neutrophils	Eosinophils	Lymphocytes	Monocytes	Basophiles
2	F	C.	17.00-109	5.01	4.01	4.90	50.0	34.0	0.979	9.0	0.83	4.09	11.70	4.33	6,400	37	3	58	1	3
		V.	15.92-102	4.92	3.98	4.82	47.0	33.8	0.984	9.0	0.83	4.00			6,250	40	0	57	3	0
2½	F	C.	11.08- 71	3.55	3.92	3.53	33.0	33.5	0.994	7.5	00	—	11.20	4.68	17,850	21	1	78	1	0
		V.	11.85- 76	3.80	4.01	3.80	35.5	33.3	1.000	7.5	00	—			17,200	37	0	59	4	0
2½	M	C.	11.08- 71	3.15	3.05	3.15	29.5	37.5	0.888	8.5	0.88	2.77	12.20	6.13	13,800	29	6	62	3	0
		V.	11.85- 76	3.44	3.30	3.42	32.0	37.0	0.900	8.5	0.88	3.01			11,800	33	1	63	6	1
2½	F	C.	9.82- 63	3.15	2.95	3.15	29.5	33.3	1.000	7.5	00	—	11.30	5.62	10,090	33	2	55	10	0
		V.	11.70- 75	3.75	3.63	3.74	35.0	33.4	0.996	7.5	00	—			11,500	32	0	60	7	1
2½	M	C.	12.48- 80	3.72	3.13	3.75	44.0	35.5	0.938	8.0	0.93	3.30	11.70	6.08	9,150	44	2	48	6	0
		V.	14.98- 98	4.57	4.43	4.55	43.0	34.8	0.948	8.0	0.93	4.00			10,050	40	2	46	12	0
3	M	C.	11.85- 76	3.70	3.51	3.64	34.0	33.8	0.984	7.5	00	—	11.20	5.84	8,850	23	0	67	10	0
		V.	11.85- 76	3.70	3.90	3.70	34.5	33.3	1.000	7.5	00	—			8,050	28	0	65	7	0
3	F	C.	15.44- 99	3.90	3.78	3.88	36.5	42.3	0.788	7.5	00	—	11.90	3.61	8,450	30	0	63	7	0
		V.	12.79- 82	3.85	4.02	3.84	36.0	35.5	0.938	7.5	00	—			8,100	29	2	65	6	2
3½	M	C.	10.65- 68	3.40	2.99	3.42	32.0	33.2	1.005	7.5	00	—	11.50	5.22	13,600	33	1	62	2	0
		V.	11.85- 76	3.54	3.82	3.53	35.8	35.8	0.929	7.5	00	—			10,900	29	2	67	3	0
3½	F	C.	11.45- 73	3.65	3.20	3.24	30.5	37.5	0.888	7.5	00	—	12.10	5.48	9,150	40	5	55	4	2
		V.	14.20- 91	4.50	3.34	3.47	35.5	43.6	0.763	7.5	00	—			9,700	33	0	62	11	0
3½	F	C.	15.60-100	5.00	4.46	4.33	40.5	38.5	0.864	7.5	00	—	12.70	5.48	12,050	44	1	40	4	0
		V.	12.79- 82	4.10	3.72	3.74	35.0	36.5	0.912	7.5	00	—			10,850	32	5	64	2	0
4	M	C.	13.85- 89	3.54	3.64	3.69	34.5	40.1	0.830	7.5	00	—	11.00	5.02	9,150	37	0	55	3	0
		V.	11.85- 76	3.75	3.49	3.53	33.0	35.8	0.929	7.5	00	—			10,000	30	2	65	5	0
4	F	C.	12.20- 78	3.80	3.70	3.73	35.0	34.8	0.955	7.5	00	—	10.09	5.05	13,050	32	2	61	6	0
		V.	12.60- 81	3.44	4.44	3.81	35.5	35.4	0.940	7.5	00	—			10,050	37	0	57	9	0
4	M	C.	14.90- 96	3.58	3.58	3.44	32.0	46.5	0.716	7.5	00	—	10.50	5.84	8,900	26	2	63	4	0
		V.	14.90- 96	3.47	3.12	3.48	32.5	45.8	0.724	7.5	00	—			9,580	33	2	61	5	0
4	F	C.	13.85- 89	3.84	3.94	3.80	35.5	39.0	0.853	7.5	00	—	11.60	3.85	8,600	43	2	50	4	0
		V.	12.70- 82	3.90	3.83	3.89	36.0	35.1	0.948	7.5	00	—			8,000	34	0	63	3	0

Age	Sex		Range																	
5	M	C.	11.45- 73	3.58	3.11	3.27	33.5	37.1	0.896	7.5	00	—	—	—	14,250	27	7	58	8	0
		V.	10.10- 64	3.23	3.01	3.17	30.0	33.6	0.990	7.5	00	—	11.90	5.66	15,050	21	2	70	7	0
5	M	C.	14.20- 89	4.12	4.15	4.03	38.5	36.8	0.906	7.5	00	—	—	—	9,150	40	0	58	2	0
		V.	13.10- 84	4.20	4.24	4.17	39.0	33.5	0.994	7.5	00	—	11.60	3.87	8,950	39	0	59	2	0
5	F	C.	14.04- 89	4.20	4.24	4.02	39.0	36.0	0.925	7.5	00	—	—	—	7,250	26	0	69	5	0
		V.	11.85- 76	3.80	4.21	3.81	35.5	33.3	1.000	7.5	1.07	4.36	11.70	5.48	8,000	28	1	68	3	0
5	M	C.	11.45- 73	3.65	4.27	4.08	38.5	29.7	1.118	7.0	1.07	4.36	12.10	5.62	8,550	27	3	63	7	0
		V.	11.45- 73	3.65	4.27	4.08	38.5	29.7	1.118	7.0	00	—	10.20	6.01	8,500	27	0	70	3	0
6	M	C.	10.25- 65	3.25	3.51	3.12	29.5	34.7	0.961	7.5	00	—	—	—	10,530	39	1	59	4	0
		V.	10.25- 65	3.25	3.19	3.22	30.5	33.6	0.991	7.5	00	—	10.20	6.06	11,350	41	1	56	2	0
6	M	C.	13.20- 83	3.90	3.77	3.83	36.5	36.1	0.923	7.5	00	—	—	—	9,900	46	1	48	5	0
		V.	13.20- 83	3.85	4.14	3.82	36.0	36.6	0.910	7.5	00	—	10.70	6.06	10,900	40	2	52	6	0
7	F	C.	14.90- 96	4.65	4.18	4.64	43.3	34.1	0.967	7.5	00	—	—	—	10,500	38	0	56	6	0
		V.	15.80-101	4.80	4.76	4.79	45.0	35.1	0.949	7.5	00	—	11.40	5.41	10,050	28	1	71	7	0
7	M	C.	12.64- 81	3.84	3.89	3.84	35.5	35.2	0.947	7.5	00	—	—	—	10,050	37	3	53	0	0
		V.	12.17- 78	3.90	3.96	3.84	35.5	35.2	0.947	7.5	00	—	11.40	6.06	10,050	41	1	58	4	1
7	F	C.	12.79- 82	4.10	3.80	3.90	36.5	33.3	1.000	7.5	00	—	—	—	11,150	26	0	70	5	1
		V.	13.42- 86	4.30	4.10	4.00	37.5	34.1	0.977	7.5	00	—	9.90	7.40	11,750	32	2	60	11	0
7	M	C.	13.26- 85	4.25	4.26	4.21	39.5	33.5	0.981	7.5	00	—	—	—	8,900	41	7	40	2	0
		V.	11.85- 76	3.80	4.72	3.80	39.5	33.5	0.994	7.5	00	—	11.10	7.40	10,900	50	0	48	3	0
7	M	C.	11.65- 75	3.75	3.65	3.77	35.5	33.3	1.000	7.5	00	—	—	—	9,600	28	1	68	3	0
		V.	11.45- 73	3.65	3.85	3.62	35.0	33.2	1.006	7.5	00	—	10.40	5.40	10,050	37	3	57	5	0
7	M	C.	11.70- 75	3.75	4.10	3.74	34.0	33.6	0.991	7.5	00	—	—	—	10,550	29	1	65	6	0
		V.	10.14- 65	3.75	3.81	3.80	35.0	33.4	0.996	7.5	00	—	12.20	6.24	8,100	31	1	62	6	0
8	M	C.	12.64- 81	4.05	3.75	4.00	35.0	28.5	1.168	7.5	00	—	—	—	9,000	29	0	64	4	0
		V.	10.45- 67	3.35	3.89	3.67	37.5	33.7	0.988	7.0	1.07	3.92	10.70	5.03	9,300	33	1	63	3	0
8	M	V.	10.14- 65	3.30	3.71	3.80	34.5	30.2	1.098	7.0	1.07	4.06	10.40	6.40	9,900	34	1	62	5	0

Total 27 cases (17 Males—10 Females)

Key: C.—Capillary
V.—Venous

CHART II

Age Group in Mos.	Males No. Cases	Hemoglobin Grams/100 cc. Blood *(Photoelectric Colorimeter 15.6=100% O₂ VanSlyke)					R.B.C. as Determined	Red Blood Cell count x10⁶/c.mm.			S.D.	C.V.	Difference & Significance Between Two Means	Cell Volume Per Cent		
		Min.	Max.	Mean	S.D.	C.V.		Min.	Max.	Mean				Min.	Max.	Mean
0-½	46	15.93	29.36	20.47	3.37	16.4	P.	4.12	6.36	5.13	1.53	23.2)	0.362 None	38.5	60.0	48.0
							H.	3.51	6.36	5.05	1.66	25.2)				
½-1	93	12.70	22.50	16.83	2.22	13.1	P.	3.41	5.84	4.71	0.84	15.7)	0.134 None	32.0	55.0	42.0
							H.	3.44	5.62	4.56	0.97	18.1)				
1-2	119	11.00	18.29	13.80	1.62	11.7	P.	3.22	5.31	4.22	0.43	9.9)	0.062 None	30.0	50.0	40.0
							H.	3.13	5.51	3.96	0.64	14.4)				
2-3	90	10.92	16.96	13.01	1.10	8.4	P.	3.28	5.59	4.03	0.46	11.3)	0.071 None	30.5	52.5	38.0
							H.	3.00	4.72	3.80	0.49	11.8)				
3-4	88	11.08	15.31	12.74	0.85	6.7	P.	3.16	4.84	3.97	0.35	8.6)	0.055 None	30.0	45.5	37.5
							H.	3.27	4.76	3.82	0.38	9.3)				
4-5	80	11.08	16.15	13.10	0.98	7.5	P.	3.31	4.99	4.04	0.41	9.9)	0.072 None	31.5	47.0	38.0
							H.	3.10	5.03	3.90	0.50	11.9)				
5-6	66	11.00	15.41	12.93	1.13	8.7	P.	3.06	5.15	3.99	0.50	12.3)	0.083 None	28.5	48.0	38.0
							H.	3.09	4.75	3.96	0.44	10.9)				
6-7	53	11.17	15.41	12.82	1.06	8.2	P.	3.25	5.03	4.06	0.34	8.2)	0.072 None	30.5	47.0	38.0
							H.	3.22	4.94	3.98	0.40	9.8)				
7-8	47	11.08	14.88	12.72	0.91	7.1	P.	3.28	4.80	4.06	0.38	9.3)	0.071 None	30.5	45.0	38.0
							H.	3.49	4.57	4.03	0.31	7.6)				
8-9	40	11.08	15.41	12.82	1.09	8.5	P.	3.55	4.88	4.10	0.34	8.3)	0.078 None	33.5	46.0	38.5
							H.	3.23	4.57	3.97	0.36	8.7)				

Age	N	Min.	Max.	Mean	S.D.	C.V.		Min.	Max.	Mean	S.D.	C.V.		None			
9-10	39	11.66	15.31	13.10	0.93	7.1	P.	3.61	5.13	4.22	0.38	9.1	0.081	None	34.0	48.0	40.0
							H.	3.43	4.76	4.09	0.33	7.9					
10-11	33	11.02	16.04	13.02	1.03	7.9	P.	3.73	5.27	4.19	0.35	8.6	0.079	None	35.0	49.5	39.0
							H.	3.45	4.76	3.99	0.30	7.3					
11-12	27	11.48	15.54	12.84	1.02	7.9	P.	3.28	4.80	4.19	0.35	8.5	0.087	None	30.5	45.0	38.5
							H.	3.55	4.71	4.01	0.29	7.0					
12-15	51	11.08	15.73	13.10	0.97	7.4	P.	3.67	4.96	4.21	0.33	7.9	0.069	None	34.0	47.0	39.0
							H.	3.39	4.68	4.03	0.36	8.6					
15-18	53	11.00	16.50	13.15	1.18	8.9	P.	3.40	5.01	4.18	0.38	9.0	0.075	None	32.0	45.0	38.5
							H.	3.23	4.92	3.99	0.39	9.4					
18-24	53	11.17	15.20	13.37	0.83	6.2	P.	3.09	4.99	4.27	0.26	6.3	0.060	None	29.0	47.0	40.0
							H.	3.03	4.56	4.01	0.34	8.3					
24-30	33	11.58	15.51	13.50	0.97	7.2	P.	3.67	4.81	4.29	0.29	6.9	0.082	None	34.0	45.0	40.0
							H.	3.55	4.60	4.01	0.36	8.6					
30-42	40	11.41	15.09	13.52	1.01	7.5	P.	3.81	4.80	4.31	0.30	7.0	0.070	None	35.5	45.0	40.0
							H.	3.54	4.54	4.12	0.32	7.4					
42-54	10	13.05	14.50	13.77	0.57	4.1	P.	3.98	4.62	4.37	0.20	4.6	0.088	None	37.5	43.0	41.0
							H.	3.97	4.54	4.30	0.19	4.3					

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Key—Minimum
Max.—Maximum
S. D.—Standard Deviation
C. V.—Coefficient of Variation

CHART III

Age Group in Mos.	Females No. Cases	Hemoglobin Grams/100 cc. Blood *(Photoelectric Colorimeter 15.6=100% O_2 VanSlyke)					R.B.C. as Determined	Red Blood Cell count $\times 10^6$/c.mm.					Difference & Significance Between Two Means		Cell Volume Per Cent		
		Min.	Max.	Mean	S.D.	C.V.		Min.	Max.	Mean	S.D.	C.V.			Min.	Max.	Mean
0-½	42	12.96	28.60	19.53	2.80	14.3	P. H.	3.99 3.63	5.79 5.77	4.91 4.84	1.44 1.55	22.9 24.0	0.321	None	37.0	53.5	46.0
½-1	52	12.18	21.04	16.72	2.48	14.80	P. H.	3.81 3.15	5.98 6.06	4.68 4.54	0.93 0.99	17.4 18.5	0.188	None	35.5	55.5	43.5
1-2	63	11.08	19.04	14.20	1.55	10.9	P. H.	3.13 3.19	5.59 4.97	4.39 3.97	0.63 0.73	13.9 16.0	0.121	None	29.0	52.0	40.5
2-3	60	11.08	16.27	12.72	1.08	8.4	P. H.	3.16 3.08	5.23 4.40	3.94 3.75	0.36 0.45	8.9 11.5	0.740	None	29.0	48.5	36.5
3-4	52	11.25	14.88	12.78	0.87	6.8	P. H.	3.31 3.13	4.84 4.81	4.05 3.87	0.39 0.42	9.6 10.4	0.800	None	30.5	45.0	37.5
4-5	50	11.08	15.93	13.23	1.15	8.6	P. H.	3.19 3.14	4.98 4.72	4.15 3.97	0.36 0.44	8.7 10.4	0.800	None	29.1	46.0	38.5
5-6	31	11.08	15.62	13.06	0.93	7.1	P. H.	3.35 3.27	4.76 4.54	4.10 3.99	0.32 0.38	7.7 9.3	0.900	None	30.8	44.2	38.5
6-7	26	11.33	15.62	13.41	1.19	8.8	P. H.	3.54 3.49	4.92 5.11	4.17 4.09	0.35 0.51	8.3 11.9	0.122	None	33.0	45.5	38.5
7-8	20	11.00	15.20	12.56	1.25	9.9	P. H.	3.35 3.56	5.76 4.71	3.93 3.90	0.63 0.31	15.9 7.9	0.159	None	30.8	53.5	36.5
8-9	24	10.92	14.12	12.78	1.09	8.5	P. H.	3.16 3.39	4.65 4.46	3.94 3.93	0.41 0.33	10.2 8.3	0.108	None	29.0	43.0	36.5

9-10	15	11.17	14.78	12.92	0.91	7.0	P.	3.47	5.11	4.05	0.44	11.0)	0.158	None	32.0	46.5	37.5
							H.	2.32	4.72	3.92	0.38	9.5)					
10-11	15	11.33	14.68	12.78	1.07	8.3	P.	3.41	4.62	4.12	0.35	8.5)	0.114	None	32.0	43.0	38.5
							H.	3.52	4.35	3.97	0.27	6.5)					
11-12	14	10.76	15.36	13.00	0.98	7.5	P.	3.64	4.54	4.03	0.24	6.0)	0.104	None	33.5	42.0	37.5
							H.	3.61	4.67	4.03	0.28	6.0)					
12-15	15	12.18	14.50	13.16	0.76	5.7	P.	3.89	4.88	4.25	0.29	7.0)	0.114	None	35.5	45.0	39.5
							H.	3.56	4.67	4.02	0.33	8.0)					
15-18	24	11.08	15.31	12.91	1.08	8.3	P.	3.31	4.99	4.10	0.42	10.3)	0.118	None	30.5	46.0	38.5
							H.	3.00	4.24	3.90	0.39	9.5)					
18-24	14	12.00	14.78	13.65	0.36	2.7	P.	4.09	4.69	4.34	0.16	3.6)	0.108	None	38.0	43.0	40.0
							H.	3.45	4.37	4.09	0.37	8.4)					
24-30	3	12.30	12.62	12.48	0.13	1.0	P.	3.93	4.02	3.96	0.54	1.3)	0.136	None	36.0	37.5	36.5
							H.	3.79	4.58	4.13	0.35	8.9)					
30-42	7	13.05	14.98	13.98	0.67	4.5	P.	4.13	4.80	4.42	0.20	4.5)	0.205	None	38.5	45.0	44.5
							H.	3.41	4.83	4.15	0.50	11.2)					
42-54	3	11.58	13.05	12.56	0.69	5.5	P.	3.67	4.18	4.01	0.24	5.9)	0.167	None	33.5	38.5	37.5
							H.	3.84	3.90	3.86	0.16	4.0)					
	530																

* Evelyn, K. A.: J. Biol. Chem., 115, 63, (1936)

Key—Min.—Minimum

Max.—Maximum

S. D.—Standard Deviation

C. V.—Coefficient of Variation

TWELVE YEARS OF REGISTRY AND ITS CONTRIBUTION TO MEDICAL TECHNOLOGY*

By KANO IKEDA, M.D.

Saint Paul, Minnesota

Introduction

With the steady and rapid advance in fundamental medical sciences and their universal and routine application in the practice of medicine and the ever broadening sphere of activities thus imposed upon the clinical pathologist, the scope of clinical pathology had of necessity widened in tremendous proportions. It had gradually developed into an exact and unified, though peculiar heterogeneously complex science in which all fundamental medical sciences found their immediate practical application. As a consequence, the clinical pathologist soon came to realize the importance of the aid which trained technical assistants, later to be known as medical technologists, could render in his practice. Indeed, his dependence upon the medical technologist has become a matter of primary necessity in the successful practice of his specialty.

Therefore, in order to primarily safeguard and promote their own interest, thinking clinical pathologists soon came to realize the imperative necessity of obtaining technical assistants who possessed adequate preliminary education and technical training. It also became evident to them that a definite line of demarcation should be drawn between the practice of clinical pathology and that pursued by laboratory workers who, in those days, represented all gradations of education, training and experience. Their qualifications varied widely. There were no agreed standards by which their qualifications might be measured. There was hardly any reputable institution of learning

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* Read before the Eighth Convention of the American Society of Medical Technologists, New York, N. Y., June, 1940.

The statements made in this paper represent only the writer's own personal views and should not in any way be construed as official.

where systematic instruction in medical technology could be had. An increasing number of hospital laboratories were admitting "cheap helpers" in the guise of "students" for a three to six month period of practical training and sending them out as trained laboratory technicians. Furthermore, a few self-seeking promotors saw an opportunity to conduct so-called schools for laboratory technicians by offering a course of from three to six months at an exorbitant fee and turning them out as graduates in a mass commercial scale.

The situation was one of utter confusion and presented one of the great stumbling blocks in the path of healthy progress of clinical pathology. When the American Society of Clinical Pathologists was organized in 1921, this fact was early recognized and possible means of its remedy was discussed at each annual meeting.

In describing the picture of confusion among the laboratory workers in those days, I am not unmindful of the very important role played by bacteriologists, biochemists and other scientific workers in the clinical laboratory practice. Many of them were pioneers in the field of laboratory medicine before clinical pathology was fully recognized as a medical specialty. Today their services are more essential than ever before. In clinical pathology, however, is being found the correlative application of the results of their labor. Their place must be adjusted accordingly.

Birth of the Registry

In accordance with the resolution passed at the Dallas meeting of the A. S. C. P. in April, 1926, the President appointed a "Committee on the Registration of Technicians" consisting of four members. The function of this committee, according to its Chairman, the late Ward Burdick, was to "first define a technician; possibly different classes of technicians, as Class A, Class B and Class C and then proceed to make it known that we have such a bureau which will undoubtedly bring forth many applications for registration. We should be able to supply institutions with competent technicians upon request".

As a member of that Committee, it was my privilege to draw up a concrete plan of carrying out its functions as outlined by the Chairman. This plan was embodied in the "Rules and Regulations of the American Registry of Medical Technicians", which, modified

from time to time, has continued to guide the administration of the Registry up to this day.

At the Washington meeting of the A. S. C. P. in May of the following year, the Committee's report, representing a vast amount of research in the problems connected with the status of laboratory technicians and including the draft of the Rules and Regulations of the American Registry of Medical Technicians was favorably received. The Committee, two more members added, was instructed to begin the registration of laboratory technicians at once but to postpone their actual classification for another year pending further study.

Exchange of ideas, suggestions and counter suggestions went on unabatedly during the subsequent fall and spring between the members of the Committee. We put forth much of our effort in arriving at a satisfactory classification of technicians and finally agreed on three classes of medical technicians, namely (a) Medical Technologist, (b) Laboratory Technician, (c) Laboratory Assistant.

In 1928, it was my privilege to prepare a report covering the results of our further study of the situation. The report included an analysis of the data contained in the three hundred and fifty applications for registration we had received up to that time which was briefly as follows: 80 per cent of them were female technicians; 52 per cent gave ages between 20 and 29; 36 per cent between 30 and 39; 21 per cent were married of which 80 per cent were male technicians; 35 per cent were college graduates and 50 per cent high school graduates; 3.5 per cent had no high school education. Among the non college graduates 41 per cent were graduate nurses and 35 per cent had incomplete nurses training; 63 per cent of the technicians without college degree received a definite course of laboratory training, 51 per cent of whom receiving it in a hospital laboratory while 31 per cent of the technicians with a college degree received such a course of training. The length of the course varied from 1½ months to 96 months. Fifty-five per cent of the registrants were employed by hospitals and 18 per cent by the United States Veterans Bureau and Hospitals. Their experience ranged from 2 weeks to 18 years. Salaries varied from 85 dollars with maintenance to 275 dollars, the average for those with a college degree being

149 dollars and for those without it 143 dollars. Male technicians, as a rule, received from 20 dollars to 30 dollars more than their sisters. The highest salary of two hundred and seventy-five dollars was paid to a non-college male technician.

The Committee also made a careful study of the curricula in order to formulate its own minimum standards of requirements and qualifications in didactic work and practical training.

The Committee recommended specifically (1) the creation of a permanent Board of Registry with functions, (a) to conduct a Registry, (b) to issue certificates of registration, (c) to conduct a placement bureau, (d) to investigate and register the schools of laboratory technicians acceptable to the Board of Registry, and (2) the adoption of the classification of Laboratory Technician and Medical Technologist, based upon the minimum standards of qualifications as defined by the A. S. C. P.

These recommendations were adopted and the Board of Registry of Laboratory Technicians was formally launched with Doctor Philip Hillkowitz as Chairman.

This, then, in brief, is the story of the beginning of the Registry. It is indeed a great privilege for me to have seen it develop from chaos and confusion to an organized force for the betterment of two allied professions, clinical pathology and medical technology.

Except for some minor changes made from time to time, the fundamental spirit and objectives of the Registry have remained the same to this day.

Contribution of the Registry

I shall outline some of the major accomplishments of the Registry in their chronological sequence in order to show that it has contributed much in the orderly evolution of medical technology from its inception to the present state.

In the beginning, laboratory technicians were classified into two groups, the Laboratory Technician and the Medical Technologist. The latter designation was issued only to those special applicants who met the rigid requirements of the Board and were individually elected at each annual meeting, while the former was given out to all technicians who met the minimum requirements without the examination. In 1931, the L. T. and M. T. were created. In 1933,

a written and practical examination was instituted to qualify for registration. In the same year, an educational exhibit was produced to be shown at various medical and hospital meetings; the work on the "model curriculum" was begun; the first conference with the officers of the Council on Medical Education and Hospitals of the A. M. A. was held to discuss the ways and means of jointly approving training schools for laboratory technicians. It was decided also to require all Medical Technologists to be college graduates and to contact colleges and universities to make the fourth year of medical technology course to be entirely practical and spent in an approved hospital laboratory. It was decided not to approve any commercial schools for laboratory technicians. In 1934, the minimum educational requirements were raised to two year college work including major sciences, to become effective in 1938. In 1935, an official examiner was appointed to correct all examination papers; automatic change of Laboratory Technicians with college degree to Medical Technologists was allowed. In 1936, it was decided to eliminate the designation of Laboratory Technician and henceforth all registered technicians were to be known as Medical Technologist. "Model Curriculum" prepared by Doctor Davidsohn was officially adopted and printed for distribution. More than six hundred copies have since been distributed. A study of the field for post-graduate work for the registrants in the various parts of the country was started.

A joint undertaking with the American Medical Association to approve schools for laboratory technicians was officially launched. It was decided to inform the laboratories which operate a training course to maintain a ratio of one student to each instructor. The Registry went on record endorsing the resolution already passed by the Executive Committee of the A. S. C. P. opposing state licensing of medical technologists. In 1939, the Board of Registry took over the editorial management of the Technical Supplement of the American Journal of Clinical Pathology. It was decided to raise the annual registration fee to one dollar and seventy-five cents and furnish each registrant with a copy of the Technical Supplement costing the Registry one dollar. A paragraph was added to the code of ethics, namely, no registered medical technologist shall instruct student technicians unless supervised by a recognized clinical path-

ologist. It was decided to admit after 1944 for examination only those applicants who had received training in a school approved by the Registry.

These are the high lights of the many actions taken by the Board of Registry since its establishment twelve years ago and represent the forward steps in the advance of medical technology. The progress has been gradual and not spectacular nor rapid as some might have hoped for. Yet, a firm foundation has been built upon which the future of medical technology may safely rest and from which further progress may confidently be expected.

Office of the Registrar

The increase in the number of registrants from some three hundred and fifty in 1928 to the present figure of more than six thousand, represents not only the actual business connected with their registrations and annual renewals but an enormous amout of work incident to maintaining an agency of this kind. The office of the Registrar is a veritable information bureau not only for prospective applicants but in all matters pertaining to medical technology and its practice. Beginning with a part time Secretary, the office now employs five full time workers to handle its business.

The Registrar is not only the manager of this growing business, but, more important, acts in a capacity of a consultant to the thousands of prospective students of medical technology and stranded or discouraged laboratory technicians who, in one way or another, are dissatisfied with their own status. Many, indeed, have been led in the right direction away from the path of questionable form of instruction and training. Many, too, have been given encouragement and counsel in the solution of perplexing personal problems which confronted them. Last year, the Registrar was in contact with the vocational guidance instructors of 20,368 high schools offering information concerning Medical Technology and wrote 781 letters to colleges and universities on the same subject. Seven hundred and seventy-six college transcripts were scrutinized during the year. In the same period, 85,401 pieces of out-going mail were handled and in the last three months 11,109 pieces of mail were received.

A few words may be said in regard to the fiscal conduct of the Registry. Utmost economy without impairing the efficiency of the

office has been practiced. The U. S. Treasury Bonds of five thousand dollars, accumulated during the first five years have been reserved for future needs. The ten dollar registration fee covers the cost of examination, including a fee to the examiner of the papers, the initial certificate, the Technical Bulletin for the first year, etc. Out of it must come the main source of income for operating expenses of the office, including the salaries of five employees, exhibit and convention expenses, equipment, etc. In recent years, little surplus has been realized for saving. The renewal fee of one dollar and seventy-five cents is apportioned roughly as follows: Technical Bulletin one dollar, certificate, postage, etc., thirty-five cents, annual letters including Roster supplement twenty cents, total one dollar and fifty-five cents, leaving a twenty cent balance toward operating expense. The books of the Registry are audited by the certified accountant and a certified report is rendered to the A. S. C. P. annually.

In connection with the operation of the Registry, mention should be made of the part which is being played by more than one hundred clinical pathologists who periodically conduct the Registry's examination. Their cooperation is indeed indispensable to the successful prosecution of the program to which the Registry is committed. The present method of having the men busily engaged in their own private practice conduct the practical examination has its drawback. It is not fool proof. Few isolated instances where the examination was given in a careless or cursory manner were reported, especially during the earlier years of our experience. We have endeavored to eliminate such defects in the manner of the examination, from time to time. Today, the clinical pathologists, as a rule, accept the appointment with the appreciation of the responsibility which is involved in the task. With added experience and consultation, we confidently expect further improvement in the present method of examination. Not in the far distant date, we may be in a position to conduct these examinations in a similar manner as the state board examinations are conducted today.

Qualifications of the Medical Technologist

As already stated, the Board of Registry is primarily concerned, first, with the proper qualifications of medical technologists now in

active practice and of those about to be trained; second, with the adequate facilities of the schools and laboratories which train them.

In the twelve years there has been gradual but consistent improvement in these requirements. The improvement has been brought about with the consent and support not only of the American Society of Clinical Pathologists but also of the American Medical Association and the American College of Surgeons.

The present minimum educational requirement of two years college work with major in medical sciences has been in effect since 1938. This provision was met with approval on the part of a great majority of clinical pathologists and by all medical technologists, who believed in the maintenance of their high professional status through the higher educational requirements and the resulting greater efficiency in service. There is today a strong sentiment among clinical pathologists as well as medical technologists, favoring complete college training for all professionalized laboratory technicians. The trend is well illustrated by the comparative study of the preliminary education among the last 422 registrants and that of some 350 applicants of 1928. The former group was represented by 54 or 12.5 per cent who had B. S. or M. S. in Medical Technology, 243 or 57 per cent who had B. S. or A. B. degree in addition to at least 12 months of approved practical training or a total of 297 or 69.5 per cent of college graduates as against 35 per cent of college graduates with or without approved training in the latter group. In addition, there were 93 or 22 per cent who had two or more years of college work plus 12 months of approved training and only 34 or 8 per cent who had only high school education or nurses training while in the latter group 50 per cent were high school graduates and 3.5 per cent had no high school education.

Approval of Schools of Medical Technology

The schools and laboratories offering a course in medical technology have also kept up their steps with technicians themselves. Today there are more than 150 approved clinical laboratories offering a course in medical technology, including thirty colleges offering a course leading to a degree in Medical Technology. These schools are inspected by a representative of the Council on Medical Education and Hospitals of the A. M. A. and found to be adequately

equipped and directed to offer an acceptable course in medical technology.

A comparison of the educational entrance requirements of 137 training schools in 1930 and those of 150 courses in medical technology listed in 1940 reveals only 11 required a college degree in 1930 and in 1940 it is required in 42; only 11 required a two year college work in 1930 against 76 in 1940; 88 required only a high school diploma in 1930 while in 1940, no schools except those offering a four year course leading to a Bachelor's degree admit high school graduates. Today there are 28 colleges listed which offer a four year course in medical technology while in 1930, there were 13 colleges and medical schools which offered a more or less unorganized course preparing the students for laboratory work.

From information at hand, I am inclined to continue to maintain the view, often expressed in the past, that private schools for laboratory technicians, commonly designated as commercial schools, are yet far short of the standards long insisted upon by the Registry and other responsible medical organizations. How to deal with these schools and treat their graduates with fairness is the question difficult of immediate solution. This cannot be realized, however, without the acceptance of the minimum requirements of the Registry by these private schools which they have so far elected to ignore.

Licensure of Medical Technologists

The questions involving the qualifications of laboratory technicians are closely linked with the problems of state licensure of laboratory workers in which this Society as well as all registered medical technologists are vitally interested. The statutory control of laboratory technicians is being vigorously sponsored by organizations composed of non-registered technicians of heterogeneous qualifications. The proponents of the measure are partly actuated by honest convictions that the present system of registrations by the Registry is undemocratic in that it fails to accord the technicians the right to govern themselves without outside interference or dictation and to provide for the recognition of the deserving many who can not meet its minimum requirements, and that it ignores the vital economic problems affecting technicians such as the minimum wage and hours. Therefore, they contend that they should assert their own inde-

pendence and advocate whatever measures of their own making to safeguard their own status.

The thesis that technicians themselves should determine the question of their educational requirement is not supported by a large number of intelligent medical technologists as well as by clinical pathologists who after all know the kind of education and training their technicians should have and who have agreed on the present minimum requirements. The proponents of state licensure, on the other hand, are cooperating with graduates of commercial schools who can not possibly meet these requirements. This would seem to indicate that they are primarily concerned with their economic status and regard lightly of the essential qualifications which usually determine the economic well being of any professional group.

In a Democracy, self government is an essential condition. However, medical technology is too closely related to clinical pathology and the medical technologist too intimately allied with the clinical pathologist to separate the former from the latter. From the very nature of our respective professions, namely their interdependence for mutual successful practice and in a sense, the complete dependence of medical technology to clinical pathology for its development and practical application in medicine, the separation of the two appears impractical and unwise. Ultimately, however, I personally see no reason why the political and economic autonomy shall not be the goal of medical technologists if they thoroughly respect the professional code governing the fundamental relationship of the two groups.

It is my opinion that in an attempt to elevate the economic status of laboratory technicians, a wise and dignified course to follow is not through compulsory legislation or unionization of workers but through the demonstration of their higher qualifications for better service. All that any legislation can guarantee is the minimum wages and not the better wages, especially if it permits lowered educational requirements. I believe that the clinical pathologist can best serve the cause by insisting on the higher professional qualifications for all medical technologists. Recently a well known medical employment agency reported that registered medical technologists were placed ten times more easily than non-registered technicians.

In this connection, it should be emphasized that the registration of technicians by the Registry is carried out entirely on a voluntary basis. Neither is there compulsion on clinical pathologists to employ only the registered medical technologists. The Board of Registry concurs with the Executive Committee of the A. S. C. P. which passed the resolution that "the employment of registered medical technologists shall not be mandatory in those laboratories where there is adequate supervision of a competent clinical pathologist".

Finally, I may quote Dr. W. D. Cutter, Secretary of the Council on Medical Education and Hospitals of the American Medical Association who states, "It was determined that the Council was in no position to feel that a state board of examiners in medical technology would represent any advance over present methods of control in this field. The experience of the Council in the licensure of physicians and the registration of nurses have indicated that statutory control in each of the 48 states would in the end be less effective than a central voluntary registration system".

Cooperation of the A. S. M. T. and the Registry

Though young in years, the Board of Registry, born in times of uncertainty and distress, has perhaps aged prematurely and assumed a paternal attitude toward its first and only child—the Medical Technologist. Therein may be found the justification for the apparent disregard with which some new policies affecting the Medical technologist as well as the clinical pathologist, have been put into effect. Nothing is further from the truth than to assert that the Board of Registry is dictatorial in dealing with its registrants. It is true that not every officer of this Society, which today represents only ten per cent of the entire membership of the Registry, has been consulted but in each instance the needs of the majority of the registrants had been explored and appreciated, before the inauguration of any new policy was done. However, to materially improve on this situation, the Board of Registry successfully sponsored an amendment to the By-Laws of the A. S. C. P. which shall permit the appointment of an advisory committee of 5 registered medical technologists to assist in the conduct of its business. I sincerely trust that this forward step may result in closer and better understanding between the A. S. M. T. and the Registry.

It is my ardent hope that the A. S. M. T. will make the most of the opportunity thus afforded by the passage of this amendment and endeavor to make our joint enterprise most profitable to the cause of medical technology as well as that of clinical pathology, always remembering that there can be no medical technology apart from clinical pathology.

There are problems of immediate concern awaiting our joint or parallel action. Steps should be taken at once to deal with such vital matters as the improvement in the economic and social status of the medical technologist, state licensure for laboratory technicians, the relation to other organizations composed of non-registered laboratory technicians, the proper disposition of laboratory assistants who have not the present requirements of the Registry, and the improvement of the official Journal of the A. S. M. T. to attract more contributors as well as subscribers. It is hoped that in dealing with these and other problems, the medical technologist and the clinical pathologist may consider and respect each other's interest before taking any definite action.

With reference to the certain menacing activities of non-registered laboratory technicians which are the source of serious concern both to the Registry and to the registered medical technologists, the Board of Registry and the Executive Committee of the A. S. C. P. are determined to combat them with vigorous campaign of education among the interested groups.

Conclusions

The contribution of the Registry to Medical Technology has been fundamental as well as practical. It may be briefly summarized.

1. The Board of Registry (A. S. C. P.) early recognized the necessity of having standardized qualifications for laboratory technicians and inaugurated a nation wide program to realize its objectives by establishing the Registry of Medical Technologists.

2. Laregly through the pioneer work of the Registry, medical technology has come to be recognized as a professional entity. It awakened and strengthened a professional consciousness in the medical technologist.

3. The Registry's adherence to its minimum requirements or, conversely its refusal to recognize laboratory technicians of inadequate education and training, is not only for the best interest of clinical laboratory service but contributes materially to the professional standing of the medical technologist.

4. The Registry has given proper guidance to thousands of prospective laboratory workers, thus contributing to the production of qualified medical technologists.

5. The Registry has endeavored to enlighten the medical profession in general of the imperative necessity of employing qualified medical technologists, through its convention exhibits, articles in medical journals by its members and correspondence, etc.

6. The Registry is instrumental in getting the American Medical Association to become interested in approving the schools of laboratory technicians and jointly with it, established the minimum essentials for approval of these schools. In so doing, it has exposed the undesirable features of commercial schools of laboratory technique.

The clinical pathologist expects much from the medical technologist not only in her efficient scientific service but in her patient willingness to cooperate with him in the furtherance of his program, the success of which, more than anything else, insures the stability and advancement of her status. In return, the medical technologist may fully expect the greater interest in and the more active encouragement for her scientific and economic aspirations. I am confident that the Board of Registry of the American Society of Clinical Pathologists stands ready and willing to lend its full support to this program.

HOOKWORM*

History, Identification, and Modes of Infection, with Laboratory Reports in Fifteen Cases

By MARIAN A. BAKER, M.T.

Taylor Laboratory, Lufkin, Texas

Hookworm disease is due to infestation of man by either of two species, Ancylostoma duodenale or Necator americanus. The adult worms live in the small intestine. Infection occurs in temperate climates, in an extreme latitude range of 51° North to 40° South, chiefly in persons coming in contact with damp earth or water containing larvae. It is characterized by discharge of the ova in stools, a progressive anemia, weakness, impaired development in the young, and varying symptoms of the digestive and nervous systems (5). It is capable of prevention by hygienic measures, and of cure by removal of the worms and iron therapy (11).

Statements in an Egyptian papyrus of 1550 BC have been interpreted as indicative of the recognition of hookworm disease. About 440 BC Hippocrates wrote of a disease which caused people to eat earth and gave infected individuals a color similar to that resulting from jaundice. Piso in Brazil (1648), Father Labat in Guadalupe (1748), and Bryon Edwards in Jamaica (1799), described conditions which would appear were due to hookworm. Before hookworm was discovered in man the presence of related species had been noted in animals. (3)

At autopsy in 1838 and again in 1842 Dubini, an Italian physician, found hookworm. These findings resulted in the systematic examination of 100 bodies, in 20 of which the parasite was discovered. An account of these findings was published in 1842 and the name Ancylostoma duodenale given the parasite.

Until 1877 hookworm infestation was recognized only at autopsy. A paper was published in Italy in 1878 by Grassi and two Parona brothers, Ernesto and Corrado, showing that hookworm disease could be recognized from ova passed in the feces. In 1879 during the construction of the St. Gothard tunnel in Switzerland an epidemic, causing hundreds of deaths and characterized by a severe anemia, occured among the miners. Perroncito demonstrated the cause to be hookworm. A great impetus to research on the subject was given by this epidemic, and the parasite was demonstrated in many countries.

Joseph Pitt (1808) was the first author to describe hookworm disease in the United States. In 1895 Dr. Allen J. Smith of the University of Texas Medical Department found hookworm ova at Galveston, Texas, and in a publication in 1901 (12) announced the discovery of the parasite in two medical students. He recognized that the worms expelled by a patient from southern Mexico were not the same as Ancylostoma duodenale, and in 1902 Stiles, working with material furnished by Smith (6), showed these to be a new species which he called Uncinaria americana, later suggesting the name Necator americanus which has subsequently been used.

The genus name Ancylostoma means "bent mouth", the species name duodenale referring to the location of the parasite in the body of the host. Uncinaria americana was considered to belong to the same genus as is found in dogs, but later was transfered to a new genus to which the name Necator, meaning "killer", was given.

The male Ancylostoma duodenale is 8-11mm and the female 10-15mm in length. The body of both male and female taper gradually to the anterior end. In the female the posterior body tapers gradually, ending in a chitinous spine. The posterior end of the male tapers to the last quarter, the tip being concealed in a bursa. The buccal capsule is slightly bent. There are two well-developed teeth on either side of the mouth, and a rudimentary pair is present at their base. There is a pair of large cephalic glands, each composed of a single giant cell, opening at the sides of the buccal capsule. Although their function is not definitely known, it has been suggested that their secretion may act to prevent coagulation of the blood of the host. The esophagus is muscular and the intestine straight,

ending in an anus near the posterior end of the body. The vulva
of the female opens at a point just posterior to the middle of the
body, the short vagina opening into two uteri. Short muscular
ovajectors are present at the juncture of the vagina and uteri. The
bursa of the male is broader than long, with a single dorsal ray
forked dorsally, with tripartite tips. The three lateral rays are well
separated. Spicules ending in a sharp point and about 2mm in
length, may or may not, project from the bursa. The color when
alive is flesh or cream, when dead it is gray or grayish-white. The
posterior two thirds is often brownish or brownish-red from ingested
blood.

The male Necator americanus is 5-10mm and the female 7-14mm
in length. They are more slender than Ancylostoma duodenale. The
body tapers anteriorly in both male and female. The female body
tapers posteriorly and does not end in a chitinous spine. The body
of the male tapers posteriorly to the last quarter, the tip being con-
cealed in the bursa. The buccal capsule is distincly smaller than in
Ancylostoma duodenale, and is bent sharply to an angle of approxi-
mately 90°. Near the base of the dorsal wall is a conical tooth-like
structure, through the tip of which the esophageal gland opens. At
the upper ventral margin are two thin cutting plates which take the
place of teeth. Cervical glands are present. The esophagus is rela-
tively shorter than in Ancylostoma duodenale. The anus is located
near the posterior end of the body. The vulva of the female is
located slightly anterior to the middle of the body. The vagina is
short and connects with two elongated muscular ovajectors which
open into the two uteri. The bursa of the male is long and wide.
The dorsal ray is bipartite and two of the lateral rays lie close
together. The spicules end in a barbed point.

The chief distinguishing points between adult Ancylostoma duo-
denale and Necator americanus are:

1. SIZE. A. duodenale is larger and thicker. The head is distinctly narrower
   than the body in N. americanus.
2. POSITION OF HEAD. The head is bent dorsally to only a slight
   extent in A. duodenale, while there is a distinct dorsal bend, usually to a
   90° angle, in N. americanus.
3. LOCATION OF VULVA. The vulva is located just anterior to the
   middle of the body in N. americanus, and just posterior to the middle in
   A. duodenale.

4. BURSA. The lateral rays are more widely spread in A. duodenale.

5. SPINES AND SPICULES. The female A. duodenale has a chitinous spine at the tip of the tail (frequently broken off), not present in N. americanus. The spicules of the male A. duodenale are sharply pointed, and in N. americanus they end in a barbed point.

Hookworms feed almost constantly except when moving to a new location on the intestinal wall or to fertilize the eggs of the female. The female Necator americanus produces from three to ten thousand eggs per day. In Ancylostoma duodenale the number produced is two to two and one half times greater.

At the time the eggs leave the body of the host they are usually in the four celled stage. The eggs are regular in outline, clear, thin-shelled, and colorless. They are ellipsoid in form, and there is a wide clear space between the shell and egg contents. The eggs of Necator americanus average 70 microns in length and 40 microns in width, Ancylostoma duodenale 60 in length and 40 in width. Although the eggs of Necator americanus are usually slightly longer with more tapering ends, the difference is not sufficient for purposes of identification.

Normally development beyond the four-celled stage does not occur until after exposure to oxygen. Three requisites are necessary for further development, oxygen, a small amount of moisture, and a moderate degree of warmth. The optimal temperature for Ancylostoma duodenale is 70-80°F, a slightly higher temperature being optimal for Necator americanus. Under optimal conditions development proceeds rapidly through 8, 16, and 32 celled stages, after which the tadpole form is assumed, gradually elongating into the fully formed embryo which soon hatches. The newly hatched embryo is about 0.25mm long and .017mm wide. After hatching, food, as well as oxygen, moisture, and warmth, are necessary. This food is usually derived from the fecal material in which the larvae are hatched. Under favorable conditions the size of the larva is doubled in about 48 hours, after which the cuticle is shed and the second larval stage is begun. After further growth the larval body retracts from, but remains inside, the cuticle, entering the third larval stage. The larvae are now ready for penetration of the host and do not feed, existing upon food granules stored in the body.

There are several points of differentiation between the larvae of Ancylostoma duodenale and Necator americanus. They are:

1. ESOPHAGEAL SPEAR. This is longer in N. americanus with straight heavily chitinized walls expanding to the form of a "Scotch thistle head". The lumen is narrow. In A. duodenale the lumen is wider, the walls not so heavily chitinized, and they do not widen out into the "thistle head".
2. UNION OF ESOPHAGUS AND INTESTINES. In N. americanus there is an open space between marked by a transverse line, not present in A. duodenale.
3. LENGTH OF TAIL. The tail is shorter and more rapidly tapering in N. americanus.
4. POSITION OF GENITAL RUDIMENT. In N. americanus this is approximately 40% of the distance from the esophagus to the anus, and approximately 50% of this distance in A. duodenale.

During the few days required to reach the third larval or infective stage, the larvae feed actively and do not migrate. In the third stage feeding stops and migration begins. The majority of the larvae are now to be found in the upper half inch of soil. If there is a surface film of moisture, the larvae may climb up on sticks, stones, or decayed vegitation, and extend their bodies into the air. The life span of infective larvae depends upon the rapidity of use of the stored food granules as well as upon environmental factors.

Although infection may occur through swallowing of infective larvae in food or water, practically all infections occur through the skin. At the time of penetration of the human skin by infective larvae the covering sheath of cuticle, from which the larva has retracted, is left on the skin of the host. The larvae break through the epidermis when sufficient leverage is available, either superficially or in the hair follicles. They find their way into the superficial lymphatic capillaries, a lesser number entering the blood capillaries. A certain percentage do not succeed in entering the lymph or blood capillaries and may live for some time in the superficial layers of the skin. Larvae which enter the lymphatics are carried to the thoracic duct and from there pass into the blood stream.

Having entered the blood stream, the larvae are carried to the right side of the heart and from there are carried through the pulmonary arteries to the lungs. The lung capillaries are only slightly elastic and hold back particles larger than their lumens, thus catching

the larvae. The larvae thus caught bore out of the capillaries into the air chambers of the lungs, probably attracted by oxygen. Having reached the bronchioles, the ciliated epithelium carries the larvae to the mouth. Upon reaching the mouth, the larvae must be either expectorated, in which case the life-cycle cannot be completed, or swallowed, the habits of the host in respect to expectoration being a controlling factor in the severity of individual infestations.

The larvae reach the trachae in three to five days, some taking longer. By the time they have reached the digestive tract a provisional mouth capsule is developed and a third moult is completed. Attachment is made to the intestinal wall of the host. Growth proceeds rapidly and sexual differentiation begins. A new cuticle is developed inside the old one which is gradually lost, carrying the provisional mouth capsule with it. With the fourth moult completed the worm grows more slowly to the adult size and the sexual organs mature. Copulation now begins and eggs appear in the stool of the host. Eggs first appear in the feces about five to six weeks after infection by os and six to ten weeks after cutaneous infection.

Fecal examination as a method of determination of hookworm infestation was first done by means of simple smears. This method was used for nearly thirty years before refinements in technique which permitted a more accurate detection of light infestations and increased the speed and efficiency of examination, were introduced. The principles involved in the later introduced methods were first, elimination of the coarser constituents of the stool by means of straining, second retention of the ova and elimination of other matter by taking advantage of the tendency of hookworm ova to adhere to glass, and third, the concentration of ova and elimination of other matter by taking advantage of differences in specific gravity, either by sedimentation or flotation, either with or without centrifuging. (4)

Differentiation of the ova of hookworm from those of other intestinal parasites is comparatively easy. The ova of Strongyloides are the only ones which may prove confusing, as they have the shape and general appearance of hookworm ova, although the shell is yellow in color. However the ova of Strongyloides are seldom found in stools as they almost always hatch out in the intestine of the host

and when ova are found, numerous larvae are also present. Hook-
worm larvae are not present in fresh fecal material. One not familiar
with hookworm ova may have difficulty in differentiating these ova
from such vegetable cells as peas, beans, potatoes, or apples. If one
will keep in mind the fact that vegetable cells are irregular in outline,
size, and shape, whereas hookworm ova are regular in these respects,
and that the outer membrane of vegetable cells dip in over de-
pressions in the nuclear material, no difficulty will be encountered.

Clinically, hookworm disease may be classified as acute which is
rarely seen; and chronic, which may be light, moderate, or heavy.
The severity of chronic infestations depends upon the age, activity,
and number of worms harbored; and upon the age, sex, occupation,
habits, nutrition, and physical condition of the host. Hookworm
causes particularly severe effects during pregnancy.

Eggs counts as a means of determination of the extent of infesta-
tion were first used in 1885 by Lutz and in 1886 by Leichtenstern.
In 1923 Stoll (14) introduced an egg counting method, using an
accurately measured sample of feces diluted with decinormal sodium
hydroxide, which gives an estimate of the number of eggs per gram
of feces. This method and its modifications have been extensively
used in investigations and as a basis for treatment. As a Public
Health measure in determining the average degree and seriousness
of hookworm infection, egg counting is valuable when applied to a
reasonable number of individuals. However, Stiles (13) and Chandler
(4) state that the many variables in egg counting detract consider-
ably from the value of this method, and that it is a poor basis of
determination for or against treatment of infested individuals.

The loss of blood in hookworm disease will affect the host in
direct proportion to his ability to make new blood. Compensation
for blood loss is maintained as long as possible, but finally there is
a reaction of the blood-forming organs resulting in a hypochromic
microcytic anemia. Wells (15) has estimated that in 24 hours one
canine hookworm will remove 0.8cc of blood. Other workers (9)
(7) have estimated the blood loss per 24 hours from one canine
hookworm to be 0.36cc and 0.1cc.

The anemia in hookworm disease may vary greatly in different
individuals. The hemaglobin may range from normal to as low as

10%, the majority in the United States averaging about 70%. Early after infection the hemaglobin usually falls more rapidly than the number of red cells, resulting in low color indices. The number of red cells is reduced slowly as the anemia progresses. Stippling is frequently present. Normoblasts are usually found, and occassionally megaloblasts are present. Poikilocytosis and polychromatophylia occur as the anemia progresses, but are never as pronounced as in pernicious anemia. Low volume and saturation indices are the rule. Due to a compensatory decreased rate of blood destruction, the icterus index is usually less than 4.0 (10).

The symptomatology of hookworm infection is predominately that of anemia (13). In order to illustrate the blood picture in hookworm disease and the rapid change which takes place upon removal of the worms and institution of iron therapy, the following report of laboratory findings is given. The patient was a boy eleven years of age, the diagnosis chronic hookworm disease.

Nov. 1, '39 Hgb. 22%; Red Cells 2,280,000; White Cells 7,000; Eos. 1%; Color Index 0.5; Volume Index 0.625; Saturation Index 0.425; Reticulocytes 6.6%; Moderate degree anisocytosis, and poikilocytosis; Marked microcytosis and hypochromia. Egg count: 20,800. Therapy instituted.

Nov. 8, '39 Hgb. 36%; Red Cells 2,730,000; Reticulocytes 11.3%.

Nov. 15, '39 Hgb. 48%; Red Cells 3,210,000; Reticulocytes 17.4%.

Nov. 22, '39 Hgb. 60%; Red Cells 3,770,000; Reticulocytes 9.0%.

Nov. 29, '39 Hgb. 74%; Red Cells 3,980,000; Reticulocytes 5.3%.

Dec. 6, '39 Hgb. 86%; Red Cells 4,330,000. White Cells 8,200; Eos. 4%; Color Index 1.0; Volume Index 1.0; Saturation Index 0.97; Reticulocytes 2.2%.

The leukocyte count is usually not significantly changed in hookworm infestation, although in massive infections leukocyte counts as high as 41,000 have been recorded (1). An elevation of eosinophiles up to 15% and occasionally higher, is common. Ashford, Payne, and Payne (1) state that the peak of eosinophilia is reached at about the end of the third month after primary invasion, and believe that this is the end of the life-span of the larvae which fail to reach and mature in the intestinal tract of the host.
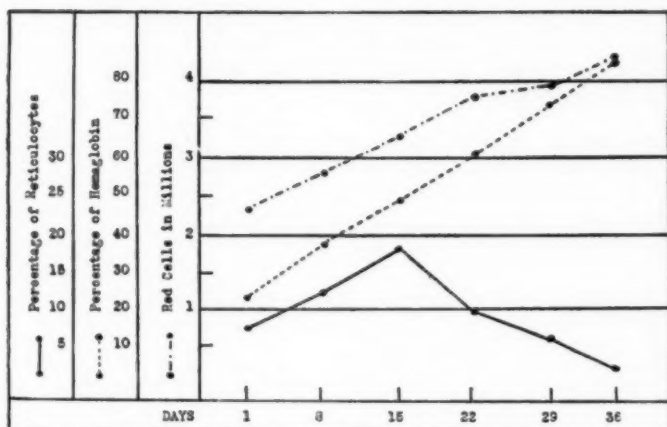
Fig. 1.   Rapid rise in red cells and hemoglobin and
characteristic reticulocyte response

In hookworm infestation calcium is decreased, chlorides are increased, cholesterol is nearly always low, and serum proteins are reduced with no alteration in the albumin-globulin ratio. (8)

The last comprehensive investigation of the incidence of hookworm disease in Angelina County, Texas, the residence of the author, was made in 1915. At that time 1,052 children between the ages of six and eighteen years were examined and 74% found to be infested with hookworm (2). In this locality the soil of loose sand and damp leaf mold supporting second growth timber, and the temperate climate, are optimal for development of the parasite. Improvement in economic and hygienic conditions, together with wide-spread treatment of hookworm disease, have markedly reduced the incidence of infestation in the past twenty-five years. Although a County survey has not been made, the laboratory and clinical records available would indicate that the percentage of children in Angelina County today infected with hookworm would not exceed 35%.

All of the cases from which the accompanying laboratory reports are taken are between the ages of six and eighteen years and are

LABORATORY RECORDS IN 15 CASES OF HOOKWORM DISEASE

Case	Age	Sex	Hgb.	Red Cells	White Cells	Eos.	Calcium	Cholesterol	Proteins	Egg Counts (3 day average)
1	15	M	67%	3,810,000	13,450	9%	7.9mg	83mg	5.2%	8,900
2	6	M	32%	2,270,000	18,600	23%	7.6mg	70mg	5.1%	14,600*
3	9	F	78%	4,360,000	4,350	14%	6.3mg	78mg	4.4%	6,100
4	7	M	84%	4,740,000	7,800	3%	9.1mg	120mg	7.3%	900*
5	18	M	56%	3,670,000	12,200	16%	7.8mg	87mg	5.1%	9,300
6	9	M	70%	4,100,000	9,500	21%	8.4mg	71mg	4.5%	8,900
7	11	F	74%	4,060,000	11,650	17%	8.6mg	105mg	6.3%	4,100
8	10	F	82%	4,430,000	5,200	8%	7.3mg	90mg	5.6%	1,500*
9	8	M	60%	3,920,000	9,250	37%	7.3mg	64mg	5.3%	7,600
10	14	F	78%	4,320,000	7,700	12%	8.2mg	96mg	5.4%	5,700
11	12	F	80%	4,770,000	6,350	7%	8.5mg	110mg	6.4%	800
12	17	F	74%	4,030,000	10,600	8%	5.7mg	83mg	3.7%	9,800
13	9	M	66%	3,900,000	11,200	15%	7.7mg	94mg	5.4%	11,200
14	13	F	78%	4,190,000	3,600	9%	5.9mg	72mg	5.3%	3,700
15	10	M	76%	4,280,000	9,750	4%	7.9mg	120mg	6.3%	5,300
AVERAGE			70%	4,056,000	9,413	13%	7.6mg	89mg	5.4%	6,500

* One Count Only,

residents of this County. Our laboratory records include cases of hookworm infestation complicated by Endameba histolytica, Ascaris lumbricoides or other intestinal parasite, or by the presence of malarial infection. For the purpose of showing laboratory findings in hookworm infestation alone, however, none of these are included in this report. The Sahli method of hemaglobin determination was used. Counting chambers and dilution pipettes for blood counting were certified by the United States Bureau of Standards. The modified Kramer-Tisdall method for serum calcium, modified Bloor's method for serum cholesterol, the Medes method for total plasma proteins, and the Stoll egg counting method were used.

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NEWS AND ANNOUNCEMENTS

REGISTRY OF MEDICAL TECHNOLOGISTS
OF THE
AMERICAN SOCIETY OF CLINICAL PATHOLOGISTS

Refresher courses for Medical Technologists are of great usefulness in keeping the laboratory worker abreast of the rapid progress in this field. The Registry of Medical Technologists heartily encourages these post graduate courses and is endeavoring to interest schools with adequate facilities to conduct seminars for this purpose.

It is intended to hold these in various parts of the country so as to make it accessible to the Medical Technologists in the vicinity to attend them.

A recent communication to the Registry on this important subject comes from Doctor S. W. Bohls, Director of Laboratories of the Texas State Board of Health, Austin, Texas. The University of Texas and the State Board of Health have cooperated in sponsoring for several years a short post graduate course for laboratory technicians and have secured a number of good lecturers and authorities in special fields of clinical pathology and public health laboratory work.

Dr. Bohls expects to have a plan worked out for a program next January, at the Bacteriology laboratory of the University of Texas. The class will be limited to one hundred technologists and an enrollment registration fee of Two Dollars will be charged. Acceptance will be made in the order of the receipt of the reservations and the registration fee.

The regular semi-annual examinations were conducted by the Board of Registry throughout the United States, Hawaii, Puerto Rico and Canada, on May 3, 1940. There were 507 applicants; 147 pathologists and their assistants gave their time and facilities for conducting the tests. 450 passed, with 39 failures and 18 cancellations. The next semi-annual class will be held in October of 1940, closing date for acceptance of applications being September 1, 1940.

WRITTEN QUESTIONS FOR EXAMINATION APRIL, 1940
(Maximum Time for Written Examination—3 hours)

I. Fill in the blood values for a normal adult male:

    1. Hemoglobin ....%........Gms. per 100 c.c.......method

    2. Erythrocyte ....per c.mm.

    3. Leucocytes ....per c.mm.

    4. Neutrophils ....%....................per c.mm.

    5.   Stabs (single lobe)....%

    6.   Segmented ....%
           (2 or more lobes)

    7. Lymphocytes ....%....................per c.mm.

    8. Color index....................

    9. Platelets....................per c.mm.

    10. Reticulocytes ....per c.mm.

II. A. Define:

    1. Leukemia

    2. Thrombocytopenia

    3. Hyperchlorhydria

    4. Achylia gastrica

    5. Achlorhydria

  B. What is meant by a "shift to the left" in the blood neutrophil count?

III. A. Give the normal values of the following in blood:

    1. Sugar in 100 c.c.

    2. Urea nitrogen in 100 c.c.

    3. Cholesterol in 100 c.c.

    4. CO_2 combining power of plasma per 100 c.c.

    5. Calcium (serum) in 100 c.c.

IV. A. If blood is drawn to the 0.5 mark and diluting fluid to the 11 mark in the pipette and the average number of leucocytes per square millimeter in the counting chamber is 18, what is the leucocyte count per c.mm.?

  B. Calculate the following in degrees of gastric acidity:

    10 c.c. of gastric juice are titrated with N/10 sodium hydroxide with the following results:

      5 c.c. to Topfer's end point. Free HCl...........degrees.

    7.5 c.c. to phenolphthalein end point. Total acidity ....degrees.

V. A. What are the important examinations made of the feces?
   B. What examinations should be made of cerebrospinal fluid from a case of suspected meningitis?

VI. A. Describe a technique of a urine test of pregnancy.
    B. Describe a test for urobilin in the urine.

VII. A. List at least 4 laboratory procedures of value in the diagnosis of hemolytic anemias.
     B. How may Treponema pallidum be detected in tissue juice?

VIII. A. Make large drawings and label the following:
         1. Ovum of two intestinal parasites.
         2. Two intestinal protozoa.
      B. What laboratory procedures are of aid in the diagnosis of trichinosis?

IX. A. Outline the procedures in the determination of Pneumococcus Types in sputum.
    B. Is it possible to differentiate between virulent and non-virulent types of C. diphtheriae (Diphtheria bacillus) on the basis of morphology, cultural characteristics or animal inoculation? If so, what are the essential differences?

X. 1. How many c.c. in 1 ounce?
   2. How many milligrams in 0.105 grams?
   3. How is 70% alcohol made from 95% alcohol? (Show the method of arriving at answer.)
   4. How much diluting fluid is added to 0.5 c.c. of serum to make a 1-200 dilution?
   5. How much sodium chloride is in a liter of physiological salt solution?

XI. Give the reaction of the following organisms to Gram's stain:
    1. Escherichia coli (B. coli).
    2. Shigella dysenteriae (B. dysenteria, Shiga).
    3. Eberthella typhosa (B. typhosus.)
    4. Brucella abortus (B. abortus).
    5. Neisseria intracellularis (Meningococcus).
    6. Borrelia vincenti (Treponema vincenti).

7. Corynebacterium diphtheriae (Diphtheria bacillus).
8. Clostridium welchii (B. welchii).
9. Hemophilus pertussis.
10. Hemophilus influenzae.

Kansas

All the serologists of Kansas were invited to attend a meeting at Emporia on Sunday evening, July 28, 1940. About 44 persons were in attendance.

Kentucky

The Kentucky Society of Medical Technologists will hold its third annual meeting in Lexington, September 15 and 16, 1940. The Entertainment Committee has planned a trip to the Narcotic Farm and Public Health Service on Sunday afternoon. On Monday the committee has announced an interesting program. Dr. E. S. Maxwell, one of Kentucky's outstanding clinical pathologists, will speak at the annual luncheon to be given at the Phoenix Hotel.

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NOTE

At the request of Dr. Peters, who wishes to make a correction, to his original article which appeared in July issue, Vol. 6, No. 4, we offer the following:

Page 171, 9th line from bottom of page: 2.7 x a x p/2 should read: 2.7 x a x 2/p.

Page 172, 5th line from top of page: New York. Should read: New York, who has also put the new ureometer on the market.